Effect of Smokeless Tobacco on Surface Roughness of Dental Restorations

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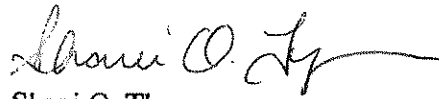Research Director

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Effect of Smokeless Tobacco on Surface Roughness of Dental Restorations

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Clinical Relevance:

Surface alterations of dental restorations can result in increased plaque biofilm. This leads to increased risk of premature restoration failure. Smokeless tobacco, commonly used within U.S. Army military personnel, represents a potential source for surface alteration. If smokeless tobacco causes an untoward effect, selection of a more resistant restorative material could increase restoration longevity, thus minimizing lost work time and costs associated with replacement of failed restorations.

Abstract:

Purpose:

Comparatively assess the effect of smokeless tobacco/salivary substitute mixture on altering surface roughness of amalgam, composite resin, and resin modified glass ionomer (RMGI) restorations.

Materials and Methods:

Sixty cubic restorations (three groups of twenty) were fabricated using a 4mmx3mm Teflon mold. One examiner assessed the restorations at time points representing zero days, one-day, one week, two weeks, one month, and three months. The data obtained were collected using a surface profilometer, measured in micrometers. Data were statistically analyzed using two-way Analysis of Variance (ANOVA) Test. A difference was significant if p<0.05.

Results:

Confidence levels with a 95% overall rating received a clinically acceptable classification. The two-way ANOVA test detected significant differences between baseline, one day, one week, two weeks, one month, and three-month data for surface roughness (p<0.05). With respect to time and restoration type, results proved statistically significant with a P value <0.0001. All restorations were statistically significant with respect to change in surface roughness with RMGIs showing the greatest surface roughness alteration.

Conclusion:

Smokeless tobacco mixed with a salivary substitute altered restoration surface roughness over time. RMGI restorations demonstrate the greatest alteration of surface roughness, with amalgam restorations showing the least. Amalgam remains the preferential restorative material in patients using smokeless tobacco.

Key words: smokeless tobacco, surface roughness, amalgam, composite resin, resin modified glass ionomer

Introduction:

Despite notable progress in reducing the prevalence of cigarette smoking in the military, smokeless tobacco use continues to increase.[1] Based on data from the Millennium Cohort Study, deployment and combat exposure in the US military are associated with an increased risk of smokeless tobacco use and smoking.[2] According to the Murtha Cancer Center, Department of Defense Cancer Center of Excellence, the prevalence of smokeless tobacco use in the military is almost four times greater compared to use in the U.S. civilian population.[3] Symptoms of post-traumatic stress disorder also increase the odds for use.[4]

Dental caries is one of the most prevalent diseases causing the demineralization of tooth structure. Streptococcus species are the predominant oral bacterial acids produced.[5] Defective restorations lead to additional loss of tooth structure due to restoration and caries removal. Factors contributing to restoration defects include: marginal leakage, polymerization shrinkage, or plaque build-up due to a high surface roughness.

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[1] Bondurant, Stuart. Institute of Medicine. Combating tobacco use in military and veteran populations. Washington, DC: The National Academies Press; 2009.

[2] Hermes ED, Smith B, Wells TS, Boyko EJ. Smokeless tobacco use related to military deployment, cigarettes and mental health symptoms in a large, prospective cohort study among US service members. Addiction. May 2012; 107(5): 983-994.

[3] Kangmin Z, Lee S. "Smokeless Tobacco use in the US Military: Accelerating Progress against Cancer through Collaboration." Walter Reed National Military Medical Center/John P. Murtha Cancer Center Presentation. 23 June 2014. http://www.wrnmmc.capmed.mil/CancerCenter/Shared%20Documents/16-Lee%20-%20 MCCCancer.pdf

[4] Boyko EJ, Gackstetter GG, Hermes ED, Miller SC, Smith, EJ, Smith TC, Wells TS. Smokeless tobacco use related to military deployment, cigarettes and metal health symptoms in a large, prospective cohort study among US service members. Addiction, 2012 May;107(5):983-94.

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Three restorative materials presently used for Class V lesions include amalgam, resin composite, and RMGI. Amalgam continues to serve as an excellent and versatile material in dentistry for more than 150 years, with an estimated 100 million Americans having amalgam restorations.[6]

Amalgam represents the material of choice for larger carious lesions in posterior teeth due to their strength, durability, ease of use, and low cost.[7] Amalgams were commonly placed in class V preparations due to their hydrophilic quality decreasing the need for moisture control. Amalgam limitations include poor esthetics, increased tooth structure removal for mechanical retention.

Composite restorations increased in popularity as a result of their tooth-like appearance, ability to conserve tooth structure, and now represent the preferred restoration amongst patients in the United States. Improvements such as refinement of filler materials with wear properties comparable to human enamel; resin materials are more predictably reliable in clinical use.[8] Composite resins are more technique sensitive, require bonding agents to maintain retention, and typically fail sooner than amalgams.

Resin modified glass ionomers (RMGIs) have the same ion-releasing glass filler particles seen in conventional GIs, but smaller. RMGIs are synthesized by reacting methacrylate with polyacrylic acid.[9] The setting reaction for RMGIs is dual cure and light activated as well as an acid-base reaction after absorption of water. RMGIs make great restorations in class five restorations due to their fluoride releasing properties in these non-esthetic regions. Their "smart behavior", which can change their behavior in response to various stimuli such as stress, heat, moisture, electricity, and pH, helps to prevent dimensional changes in moist environments.[10]

Compared to other restorative materials, one advantage of glass ionomers is their placement in cavities without the need for bonding agents.[11] Despite these positive biocompatible features, their weakness lies in the lack of sufficient strength and toughness.[12] To improve some of these weak glass ionomer properties, the creation of

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[6] Ritter A, Talking with Patients: Dental Amalgam. JERD 2003; 15(5): 319

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[12]

RMGIs helped to improve flexural strength through the introduction of hydrophilic monomers and polymers like hydroxylethyl methacrylate.[13]

Resin composites and RMGIs are the most common types of adhesive materials used to restore cervical lesions.[14] Ideal esthetic properties of composite resins and the fluoride releasing properties of RMGIs make these two restorations a good fit. The more comparable modulus of elasticity of both restorations compared to enamel also allows for ideal abfractive properties. Amalgams have a solid record of longevity far outlasting those of composite resins and RMGIs with less inclination to recurrent decay. Understanding these properties help dentists decide which restorative material to utilize when treating deploying Soldiers who use smokeless tobacco.

Smokeless tobacco, which contains high sugar content and acidic properties, also contributes to caries onset, destruction of enamel and other tooth structures.[15] As a result, smokeless tobacco use could result in a greater number of early failures of restorations, especially Class V cervical restorations.

Various studies investigated the influence of surface structure and composition of dental restorative materials on bacterial adhesion.[16] The overall conclusion from these studies is that surface roughness is positively correlated with plaque accumulation.[17] Findings also demonstrate that increased surface roughness would prompt non-uniform stress distribution, mainly due to the shape differences in the surface layer.[18] Ultimately this leads to craze lines, cracks, or even fractures in the restoration causing inflammation

Keshani F, Khoroushi M. A review of glass-ionomer: From conventional glass-ionomer to bioactive glass-ionomer. Dent Res J (Isfahan). 2013 Jul-Aug; 10(4): 411–420.

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of the dental pulp if not properly treated. Mecholsky et al announced this theory which initiation of cracks starts at stress concentration points caused by surface roughness.[19]

Given the rising rate of smokeless tobacco use in the armed forces, it is critical to understand how different dental materials respond to smokeless tobacco exposure. To answer this question, the present study evaluated the effect of smokeless tobacco/salivary extract on three commonly used dental materials with differing surface roughness (Ra, um).

Materials and Methods:

Sixty restorations, divided into equal groups of twenty (twenty amalgams, twenty RMGIs, and twenty composite resins), evaluate effects of smokeless tobacco and salivary extract solution combined liquid extract (Copenhagen long cut straight and Hanks Balanced Salt Solution) on the surface roughness of different restorations. Materials used, compositions, and product manufacturers used are listed in Table 1.

Table 1: Materials to test the effect of smokeless tobacco exposure on surface roughness

Material	Type	Contents	Manufacturer	Location
Amalgam	Valiant PhD (regular set)	59% Ag, 13% Cu, 43% Hg, 28% Sn	Kerr	Charlotte, NC
Composite resin	Filtek Supreme Ultra Universal	Bis-GMA, UDMA, TEGDMA, Bis-EMA (6) resins, silica filler, zirconia filler	3M ESPE	St. Paul, MN
Resin Modified Glass Ionomer	Fuji II LC	silicate glass powder, polyalkenoic acid, HEMA, UDMA	GC America	Alsip, IL

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[19]

Mecholsky J, Freiman S, Rice R. Effect of grinding on flaw geometry and fracture of glass. J Am Ceram Soc. 1977;60:114–7.

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Copenhagen Tobacco	long cut straight	water, tobacco, sodium chloride binders, natural and artificial flavors, ammonium chloride, ethyl alcohol, ammonium sodium carbonate preservatives (10 mg)	U.S. Smokeless Tobacco Company	Nashville, TN
Surface Profilometer	Surface Roughness Tester Surftest SJ-210	2.4in color graphic LCD, calculation results assessed profiles, load & amplitude curves	Mitutoyo Corporation	Japan
Dykstra EMS Embedding Mold	Stepped Microtome Catalog # 70907	Teflon	Electron Microscopy Sciences	Hatfield, PA
Curing Light	Mini L.E.D. (Light Emitting Diode) #303677-019	Power module Handpiece Eyeshield	Acteon Satelec	California U.S.A.
Simulated Salivary extract	Hanks Balanced Salt Solution, 1X	10mL	Corning Cellgro	Manassas, VA
Matrix Strips	DuPont Mylar 10cmx0.95cm MFG#20 95-8205	plastic strips measure 4" x 3/8" x 0.002"	Patterson Dental Supply	Montreal, Quebec
Laboratory Incubator	Heratherm Oven Mo # 3700-87	97.2 degree Fahrenheit temperature	Thermo Scientific	Anaheim, CA
Reclosable container lid	0.55 liter clear plastic	none	Solo Cup Operating Corporation	Highland Park, IL
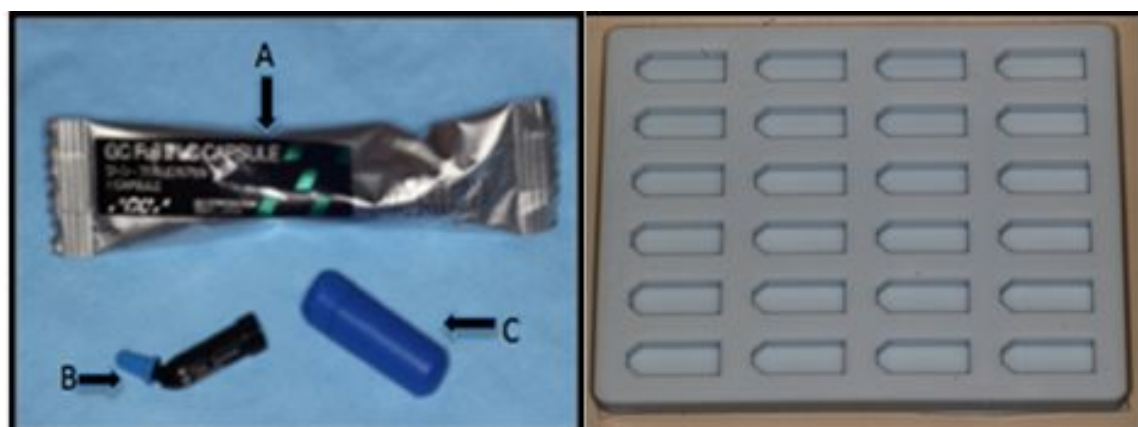
Figure 1: Dental Restorations (A-RMGI, B- Composite,C- Amalgam) and Sample

Embedding Mold

Figure 2: Copenhagen long cut straight Tobacco

Specimen preparation:

The restorative materials called for the preparation of twenty cubic specimens each, using a 4 mm x 3mm Heliotest Teflon mold (Electron Microscopy Science, Catalog # 70907, Hatfield, PA). The prepared materials slightly overfilled the molds. Careful preparation of the composite resin and RMGI occurred with proper isolation and light cure with the use of a mylar strip (DuPont Mylar, MFG #20 95-8205, Montreal, Quebec) to help remove voids and excess material. A LED light cure unit (Mini L.E.D. (Light Emitting Diode) #303677-019, California U.S.A.) with a light intensity of 665m W/Cm cured and polymerized the composite and RMGI according to the manufacturer's instructions. Amalgams fully set over the 24-hour setting period.

Following specimen preparation, all restorations were polished, then soaked in normal saline at 37 degrees Celsius for 24 hours. Preparations were blotted dry and initial measurements taken with a surface profilometer (Mitutoyo surface roughness tester- Surftest SJ-210) to determine baseline surface roughness. Baseline measurements represent control values.
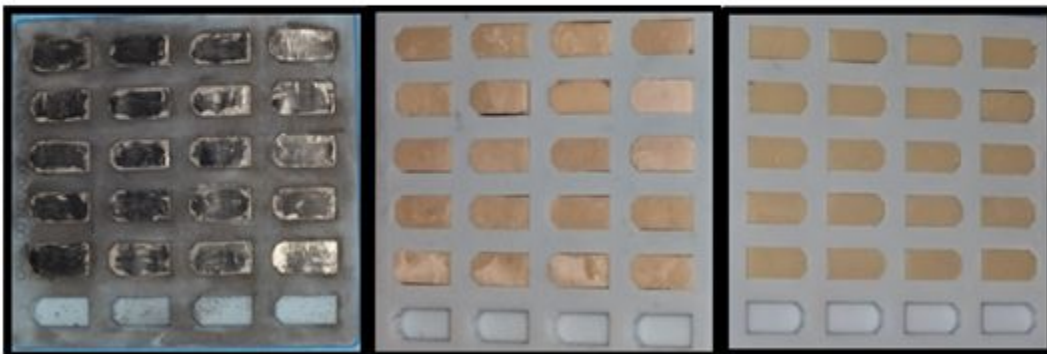

Figure 3: Amalgam, Composite resin, and Glass Ionomer restorations in embedding molds

The examiner stored specimens in 97.2 degree Fahrenheit heratherm laboratory incubator (image 13 and 14) during the duration of the experiment to represent the average temperature of the human mouth. Ten mg of the Copenhagen smokeless tobacco and 10ml of the salivary substitute liquid mix fully covered each type of restorative material for 24 hours a day. The examiner measured the surface roughness after 6 hours (representing one day), two days (representing one week), 3.5 days (representing two weeks), six days (representing one month), and 15 days (representing two months). The need to evaluate the surface degradation at shorter time intervals occurred due to the limited time constraints. The surface profilometer, an instrument which measures a surface's profile, in order to quantify its roughness, helped evaluate and quantify the surface roughness of the restorations. The average surface roughness (Ra) is the average value of the "height of the surface profile above and below the centerline throughout the determined sampling length.[20]
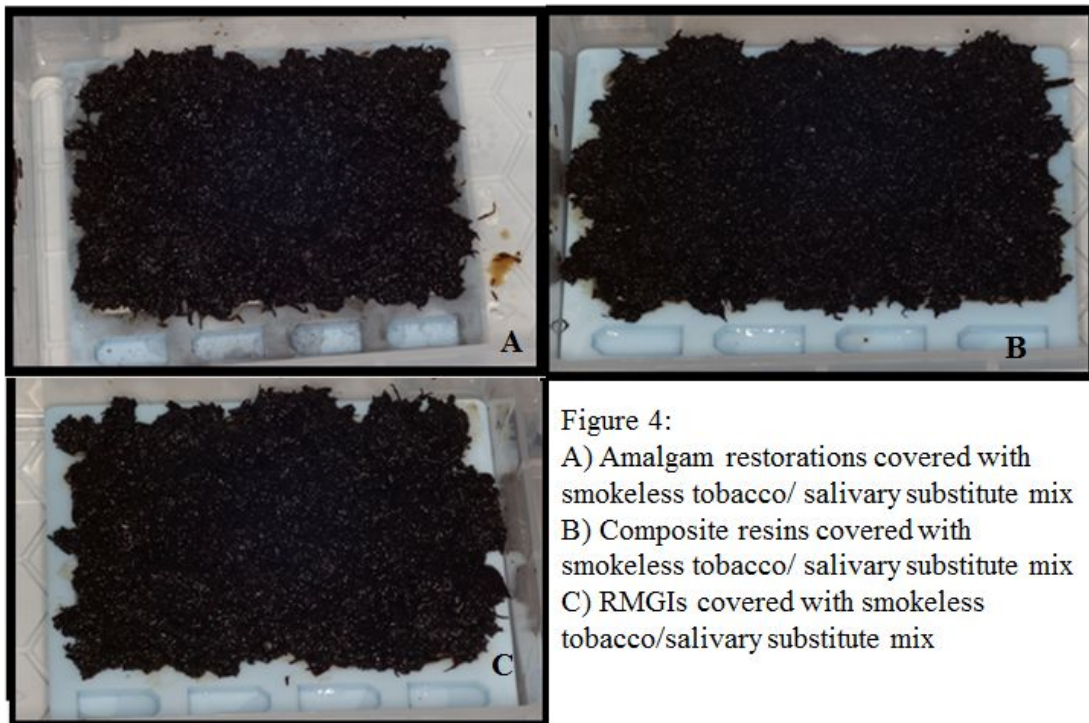

Figure 4:
A) Amalgam restorations covered with smokeless tobacco/ salivary substitute mix
B) Composite resins covered with smokeless tobacco/ salivary substitute mix
C) RMGIs covered with smokeless tobacco/salivary substitute mix

In total, sixty prepared specimen, divided into three groups were evaluated; Group 1, Valiant PhD (n=20); Group 2, Filtek Supreme Ultra Universal (n=20); and Group 3, Fuji II LC (n=20)

Evaluation and Data Collection:

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One independent examiner placed and evaluated all restorations and collected data. The examiner accurately calibrated the Surftest SJ-210, surface profilometer by measuring the precision roughness specimen supplied with the profilometer set, per manufacturer guidelines. The examiner also adjusted the gain to ensure the measured value equaled Ra (nominal value) of the precision roughness specimen.

A calibrated surface profilometer found the average surface roughness (Ra, in um) of the specimen. An initial roughness measurement taken represented the roughness value, unless the profilometer could not read the initial roughness value. If this occurred, the examiner moved the profilometer to an area where the device could obtain a reading. If the surface was too rough to gain a second reading, then a null value was annotated.

Figure 5: Surface profilometer surface roughness tester

Statistical Methods:

A two-way ANOVA test, utilizing the same materials, analyzed intragroup comparisons between baseline and varying timelines. Evaluating row and column factors tested statistical significance of results with respect to time, restoration, and the interaction between the two factors. The alpha value was set at 0.05. Data are represented as means (+/- SEM) and experimental manipulations performed in a parallel manner. Dunnett's multiple comparisons test indicated the data collected were distributed normally and are statistical significance. Graph Pad Prism statistical software carried out all statistical analysis.

Results:

Zero restorations were lost due to misplacement or extreme chemical wear. Fifty-two readings were discarded because the profilometer could not read the roughness measurement range for specific time points. Initial illegible readings presented at hour 222 of data collection. Despite illegible readings at a specific time point, restorations presented a legible reading on the next available measurement period.

Time:

When evaluating the change percentage of surface roughness over time, all restorations showed a steady to large change in roughness. Amalgams showed an overall 20% increase during the modeled two-month testing period. Figure seven shows a small

increase in surface roughness from baseline to completion of the data collection. There was a steady movement with a slight change over time. The highest surface roughness recording appeared at the simulated one month and one day mark (186 hours) and the lowest surface roughness recording appeared at baseline.

RMGI showed the greatest overall percent change with a 237% increase over the represented two-month period. Figure seven shows a large increase over time from baseline to completion. The highest surface roughness recording appeared at the modeled two-month period (360 hours) and the lowest recording appeared at baseline. Composites showed the most fluctuation with an overall 31% decrease over the represented simulated two-month period. See figure 7 to see the fluctuation of this restoration. The highest surface roughness recording emerged at the one-week mark (45 hours) and the lowest recording emerged just shy of one month.

All of the results followed suit with the hypothesis showing statistical significance for an increase in surface roughness overall. The total percent of variation for all restorations combined showed a row factor of 0.7672, yielding a P value of less than 0.0001 suggesting the results are statistically significant and stay within the confidence interval.

Restorations:

When examining the restorations from a clinical standpoint, a significant change in color and clinical roughness existed for all restorations when viewed clinically. RMGIs showed a distinct staining and change in surface texture (see image 18). The percent of total variation for the column factor was 67.73, yielding a P value of < 0.0001, satisfying the confidence interval.
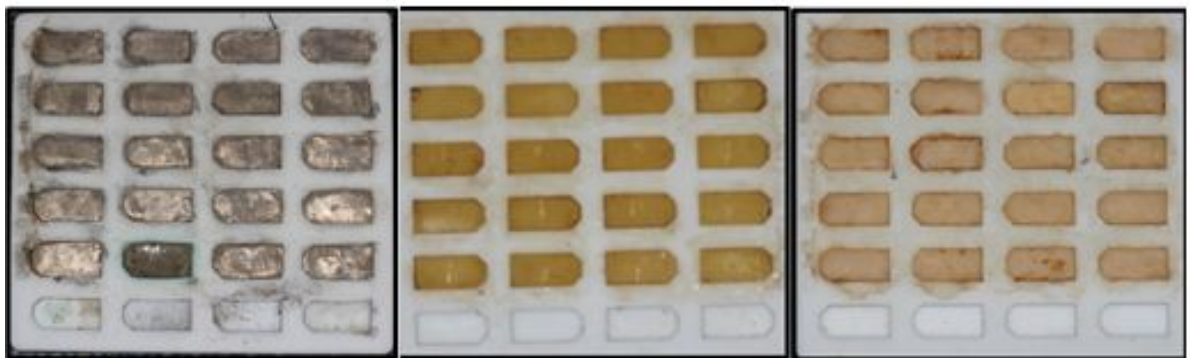

Figure 6: Amalgam, Composite resin, RMGI restorations respectively after 360 hours after testing

Interaction of Time with Respect to Restoration:

Data shows that the amalgam restoration did not change surface roughness much over time, compared to the gradual, then rapid rise in surface roughness detected in the glass ionomer material. Regarding the interaction of time with respect to the restoration, data shows statistical significance with a total percentage of variation of 4.2%. Surface roughness of different restoration types yielded statistically significant variances among each other after smokeless tobacco exposure ($F_{(60, 3425)} = 1.607$; $p < 0.005$). There was a significant interaction between time and restoration type ($F_{(2, 3425)} = 4255$; $p < 0.0001$).

The P value, < 0.0001, satisfied the confidence interval of greater than 95%. The two-way ANOVA evaluated comparisons of specimen mean scores. The ANOVA revealed statistically significant variances for all restoration types in respect of time ($F_{(120, 3425)} = 4.398$; $p < 0.0001$). Dunnett's multiple comparisons test indicated the data collected were distributed normally and are statistical significance. Graph Pad Prism statistical software carried out all statistical analysis. Data are represented as means (+/- SEM) and experimental manipulations performed in a parallel manner.
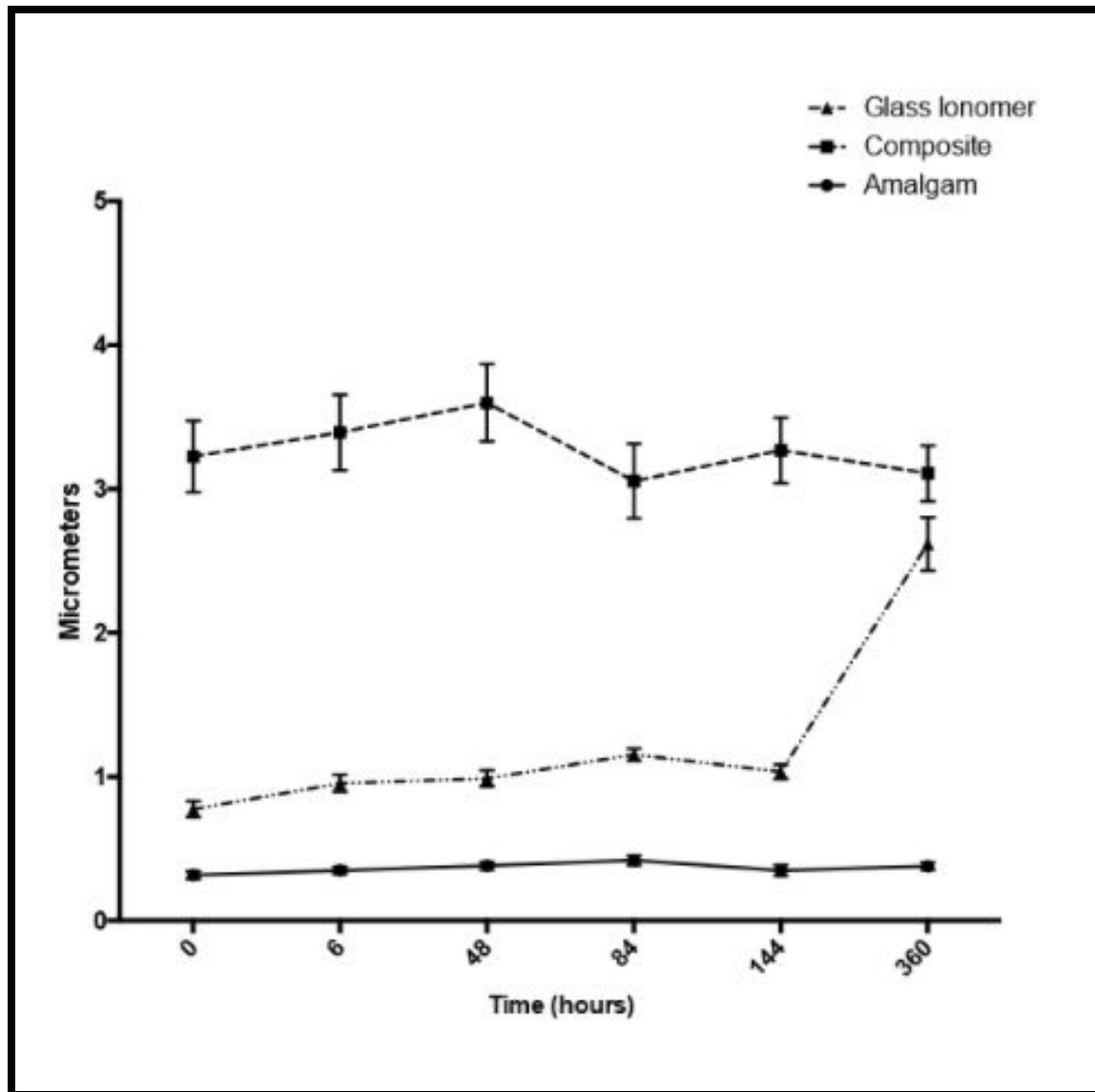
Figure 7

Discussion:

Studies have shown an increased use of smokeless tobacco, especially among deployed military personnel.[21] Reasons for smokeless tobacco use include helping to stimulate moisture in the mouth, addiction to nicotine, and peer pressure. Ingredients found in smokeless tobacco include: polonium 210, n-nitrosamines, formaldehyde, nicotine, cadmium, cyanide, arsenic, benzene, and lead, to name a few. Natural and

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[21]

Hermes ED, Smith B, Wells TS, Boyko EJ. Smokeless tobacco use related to military deployment, cigarettes and mental health symptoms in a large, prospective cohort study among US service members. Addiction. May 2012; 107(5): 983-994.

artificial flavors, preservatives, and sugars are also added. Polynuclear aromatic hydrocarbons, polonium 210, and n-nitrosamines represent the chemical carcinogens.[22] Another study shows 70% of tobacco-specific N-nitrosamines (TSNA) becomes extracted from one dip of snuff when kept in the mouth for 30 mins.[23]

The pH of smokeless tobacco ranges from 5.84 to 8.1 with a nicotinic content ranging from 0.42% to 2.73%.[24] Although the average pH is more neutral to basic, the large amount of sugar, preservatives, and chemical carcinogens of smokeless tobacco have an association with gingival recession, tooth wear, and dental caries in users.[25] Long-term clinical success of dental restorations depends on various factors, including the physical properties of the material, clinical proficiency of the treating dentist, and proper maintenance and patient care. Understanding whether there is a change in surface roughness is important because "irregularities in surface texture enhance bacterial adhesion, and roughened materials may suffer from increased staining."[26] Increased bacterial adhesion increases the incidence of recurrent decay and defective restorations.

The three restorative materials used in this study showed varying results most likely due to the differences in their material structure. Due to their organic matrix, resin materials are more prone to chemical alteration compared to metal or ceramic restorations.[27] This might help to explain why the amalgam group showed the smallest change in surface roughness compared to the composite resin and RMGI groups.

Different studies comparing amalgam and resin-based composites as restorative materials suggest amalgam has greater longevity than resin-based composites. One randomized clinical trial revealed the risk of experiencing secondary caries as 2.5 times greater with composites.[28] In another study, amalgam outperformed resin

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[22]Main JH, Lecavalier DR. Smokeless tobacco and oral disease. *J Can Dent Assoc* 1988; 54:586- 91.

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[28] Bernardo M, Luis H, Martin MD, et al. Survival and reasons for failure of

based-composites, showing a 94.4 percent amalgam survival rate at seven years compared with 85.8 percent for resin-based composites at seven years.[29] Improved survival rates of amalgams may be attributed to the less technique sensitive nature of placing them, expansion of amalgam upon setting which decreases onset of marginal leakage, and a greater ability to withstand occlusal forces.

      RMGI showed the greatest change in surface roughness with a statistically significant steady and gradual increase noted throughout the entire 360 hours of testing. This increase also showed clinical evidence with visible roughness and staining. The large sensitivity of RMGI to smokeless tobacco may be attributed to a weak organic matrix. While RMGIs perform well with retention and post sensitivity, it is not reliable in terms of marginal characteristics, surface properties, and color stability.[30] For this

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amalgam versus composite posterior restorations placed in a randomized clinical trial. JADA 2007;138(6):775-783.

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AUTHORS

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reason, a RMGI may not be the restoration of choice for a patient using smokeless tobacco.

Smokeless tobacco also had a significant effect on the surface roughness of composite resin. The results for this material fluctuated differently from the amalgam and RMGI. Values for the surface roughness remained steady for the first half of the experiment until a sharp drop in roughness was measured around the halfway point. From that point on, the roughness continued to gradually increase. This is the only restoration which reacted contrary to initial clinical expectations clinically. Despite the clinical variability, statistics showed a significant overall increase in roughness.

Composite resins may have reacted with such clinical variability due to human error. Future studies may benefit from an extended time period of testing, which may help show a larger data set of the clinical exposure of the restoration composition change. In a previous study observing the effect of in-office bleaching agents, carbamide peroxide and hydrogen peroxide, results showed a slight increase in the surface roughness of the

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Date: 05/01/2016

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composite resin tested, but the increase in this experiment did not show statistical significance.

Filtek Supreme Ultra Universal, the nanofil resin used in this study has a well-rounded appeal because of its equal mix of esthetics and strength. Its translucency is also appealing. Composite resins, in this experiment, did not show the most resistance to smokeless tobacco like amalgam, but it also did not show the large change in roughness in comparison to RMGIs. Additional testing may be beneficial focusing on the relationship smokeless tobacco has on the composite resin to gain more understanding.

When reviewing and evaluating overall experiment results, it is important to remember, this study only takes into account the effect a smokeless tobacco mix has on the surface roughness of dental restorations solely from a chemical perspective. Objectively, smokeless tobacco use has more than just a chemical effect. The largest effect is abrasive in nature. The natural state of the tobacco is a graininess, which contributes the abrasive effects. Additional studies accounting for both chemical and abrasive effects of smokeless tobacco will provide an even greater understanding of this topic. In retrospect, the gold standard for truly measuring the surface roughness of a specimen would be use of a scanning electron microscope (SEM).

Nonetheless, our results of this study demonstrate distinct, measurable differences among common dental restoration materials when exposed to smokeless tobacco. These findings provide a framework for future studies such as SEM experiments. Additionally, the results presented here add to the literature to better inform dental clinicians, particularly those treating military personnel, when selecting restoration materials. .

Conclusion:

Both quantitative and clinical observations show the distinct effect that smokeless tobacco/salivary substitute mix has on surface roughness of common dental restorations. Amalgam (Valiant PhD), which represents the oldest and strongest restoration, showed the smallest change over time. RMGI (Fuji II) showed the greatest percentage of surface roughness change with a distinct clinical staining over a period equivalent to two months.